Geophysical Research Abstracts
Vol. 17, EGU2015-9583, 2015
EGU General Assembly 2015

A re-analysis of 533 rockfalls occurred since 2003 in the Mont Blanc massif for the study of their relationship with permafrost

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Rockfall is one of the main natural hazards in high mountain regions and its frequency is growing, especially since two decades. Collapses at high elevation are with an increasing certainty assumed to be a consequence of the climate change through the warming permafrost.
In the Mont Blanc massif, data on present rockfalls (occurrence time when possible, accurate location, topographical and geological settings, volume, weather and snow conditions) were acquired for 2003 and for the period 2007-2014 thanks to a satellite image of the massif and a network of observers in the central part of the massif, respectively. The study of the 533 so-documented rockfalls shows a strong correlation at the year scale between air temperature and rockfall.
Along with this data acquisition, a statistical model of the Mean Annual Rock Surface Temperature (MARST) for the 1961-1990 period has been implemented on a 4-m-resolution DEM of the Mont Blanc massif. The model runs with Potential Incoming Solar radiation (PISR) calculated with GIS tools and air temperature parameters computed from Chamonix Météo France records.
We cross here the data on rockfalls with the permafrost distribution model to show that: (i) rockfall occurs mainly over modeled negative MARST (context of permafrost); (ii) simulated warm permafrost areas (> -2°C) are the most affected by instabilities; (iii) as the 1961-1990 period is supposed to be representative of the conditions at depth that are not affected by the climate warming during the two last decades, the latest results are mainly valuable for rockfalls related to pluri-decadal signal; and (iv) the higher (close to 0°C) the MARST, the deeper the detachment (possibly related to the deepening of the permafrost active layer). These results and field observations confirm that warming permafrost corresponds to the main required configuration for rockfall triggering at high elevation. In addition, we show that rockfalls for which ice observed in their scar indicates the presence of permafrost can be used to validate the permafrost distribution model.